

SPRINGTIME MOVEMENTS, ROOST USE, AND FORAGING ACTIVITY OF TOWNSEND'S BIG-EARED BAT (*PLECOTUS TOWNSENDII*) IN CENTRAL OREGON

David S. Dobkin¹, Ronald D. Gettinger², and Michael G. Gerdes³

ABSTRACT.—Seasonal movements, roost-site fidelity, and foraging activity patterns are largely unknown for western populations of Townsend's big-eared bat (*Plecotus townsendii*). We used miniature radiotelemetry units to track springtime movements of six bats inhabiting forested lava flows in central Oregon, and found that bats moved up to 24 km from hibernacula to foraging areas. Individual bats returned to the same foraging area on successive nights but shifted to different areas in presumed response to changes in insect availability. Both sexes apparently use a series of interim roost sites between emergence from hibernation and the time females enter into maternity colonies, with little individual fidelity to these sites. In regions characterized by extensive lava-flow topography, suitable daytime roosts are numerous and dispersed over a large area, allowing bats to move relatively great distances to locate foraging ranges. Hence, the actual area of concern for effective management of individual populations can be considerably larger than indicated solely by locations of hibernacula and maternity caves of this declining species.

Key words: Townsend's big-eared bat, *Plecotus townsendii*, foraging movements, roost sites, roost fidelity, hibernacula, caves, central Oregon, radiotelemetry, lava flows, candidate species.

Townsend's big-eared bat (*Plecotus townsendii*) is distributed over much of western North America (Hall 1981), although populations may be widely scattered within its range. The species appears to be a habitat generalist, reportedly inhabiting coniferous forests in northern New Mexico (Jones 1965), mixed mesophytic forests in Kentucky (Adam et al. 1994), deserts in Arizona (Hoffmeister 1970), native prairie in Kansas and Oklahoma (Humphrey and Kunz 1976), riparian communities in northeastern Montana (Swenson and Shanks 1979), Kansas, and Oklahoma (Humphrey and Kunz 1976), and agricultural areas and coastal regions in California and Washington (Dahlquest 1947, 1948, Pearson et al. 1952). In Oregon the distribution of Townsend's big-eared bat is discontinuous and highly local across forest and shrubsteppe habitats throughout the state (Perkins and Levesque 1987).

Two disjunct subspecies occur in eastern North America, both of which are listed as endangered under the U.S. Endangered Species Act. Kunz and Martin (1982) suggested that western populations also are vulnerable, especially to disturbance in winter hibernacula and summer maternity caves. Both subspecies

found in the western United States are declining markedly (Perkins and Levesque 1987, Pierson et al. 1991), and the species is listed as endangered, sensitive, or of special concern by several western states and federal land management agencies.

Big-eared bats feed almost exclusively on Lepidoptera (Ross 1967, Whitaker et al. 1977, 1981, Dalton et al. 1986, Sample and Whitmore 1993) and are viewed as moth specialists (Dalton et al. 1986, Sample and Whitmore 1993). Probably most limiting to their distribution, however, is availability of suitable sites for roosting, hibernation, and reproduction, which consist primarily of caves and abandoned mines. These three activities require different microclimatic conditions (Dahlquest 1947, Pearson et al. 1952, Twente 1955, Barbour and Davis 1969, Martin and Hawks 1972, Humphrey and Kunz 1976, Marcot 1984, Genter 1986, Perkins and Levesque 1987, Pierson 1989, Pierson et al. 1991, Lacki et al. 1993, Clark et al. 1995). Any single site generally is unsuitable for more than one function, although microclimates in different regions of the same cave sometimes differ sufficiently to accommodate more than one activity (e.g., Clark et al. 1995).

¹High Desert Ecological Research Institute, 15 S.W. Colorado Avenue, Suite 300, Bend, OR 97702.

²Biology Department, Randolph-Macon Woman's College, Lynchburg, VA 24503.

³Deschutes National Forest, United States Forest Service, 1645 Highway 20 East, Bend, OR 97701.

Big-eared bats are colonial for most of the year, but colony dynamics and seasonal movements have not been studied in the Intermountain West. In central Oregon, *P. townsendii* undergoes arousal from hibernation and movement from hibernacula in April, although the precise timing of these events appears to vary with weather conditions and topography (U.S. Forest Service, Deschutes National Forest, unpublished data). Females form maternity colonies in late spring or early summer (USFS unpublished data), but the timing of their arrival at maternity roosts is poorly documented, and it is unclear whether they move immediately to maternity roosts upon departure from hibernacula.

A much better understanding of seasonal movements among roost sites is necessary for effective management of populations. Although it is clear that traditional site use (sensu Dobkin et al. 1986) occurs for specific hibernacula and maternity roosts, the extent of roost site fidelity by individual bats is unknown. Recent telemetry studies have been conducted for both endangered subspecies found in eastern North America (Clark et al. 1993, Adam et al. 1994, Lacki et al. 1994), but no telemetry studies have examined the movements of western subspecies. Our primary objective was to acquire information concerning the extent of movements by individual Townsend's big-eared bats during the period following arousal from hibernation in an area containing a significant proportion of Oregon's known population.

STUDY AREA AND METHODS

Fieldwork was conducted in Deschutes County on the Fort Rock Ranger District of the Deschutes National Forest and adjacent lands administered by the Bureau of Land Management. The primary study area (Fig. 1) consists of a NW-SE-oriented basin containing extensive forested lava flows, and the surrounding buttes from 44°25' to 43°37' N, and 121°15' to 120°48' W. Elevations range from 1400 m on the basin floor to nearly 2000 m atop Pine Mountain. Forests are open stands of ponderosa pine (*Pinus ponderosa*) with bitterbrush (*Purshia tridentata*), manzanita (*Arctostaphylos* spp.), and bunchgrass understories. Scattered, relatively closed, stands of lodgepole pine (*P. contorta*) also occur throughout. Areas adjacent to lava flows consist of shrub-

steppe habitat dominated by sagebrush (*Artemisia tridentata*).

The study area lies within the broad zone of intergradation between the western interior form (*P. t. pallescens*) and the coastal Pacific form (*P. t. townsendii*) of Townsend's big-eared bat (Handley 1959). We concur with Handley's (1959: 199) assessment that "allocation . . . from much of this area to one race or the other is largely a matter of personal opinion."

Based on USFS cave surveys conducted from 1985 to 1991, two hibernacula (S1 and S2, Fig. 1) but no maternity caves were known from the southern end of the basin. The northern end of the basin contained a series of hibernacula and one maternity cave (N3, which was gated), as well as one other cave (N2) that reportedly was used as a maternity roost in the past. The maternity cave and the northernmost hibernaculum in the southern portion of the basin are separated by 30 km, which prompted the assumption that big-eared bats in the basin consisted of two separate populations (J. M. Perkins, unpublished report to USFS). Subsequent to completion of our fieldwork, a previously unknown maternity cave was discovered beyond the southern end of the basin, 17 km southeast of S1.

Fieldwork in 1992 commenced on 7 April and continued through 9 June. Six big-eared bats (5 females, 1 male) were captured by hand between 1100 and 1730 h from four different caves in April and May (Table 1). Each bat was fitted with a battery-powered (14–21 day battery longevity), miniature radiotransmitter (0.6–0.7 g; Model BD-2B, Holohil Systems, Ltd.) affixed to the dorsal, interscapular fur (Dobkin et al. in press) with eyelash cement. Transmitter units averaged 6% of bat body mass (\bar{x} = 10.6 g, Table 1), which should have had minimal effect on maneuverability and energy costs for this species (Davis and Cockrum 1964, Aldridge and Brigham 1988).

Bats carrying transmitters were tracked with portable receivers (Telonics) equipped with directional antennae (Wilkinson and Bradbury 1988). Bats were monitored for nearly 850 observer hours over the 64-day period through a combination of daytime ground searches and nighttime triangulations from fixed locations. Two or three observers with receivers were located on the tops of buttes widely separated around the basin (Fig. 1) to provide the directional data necessary for

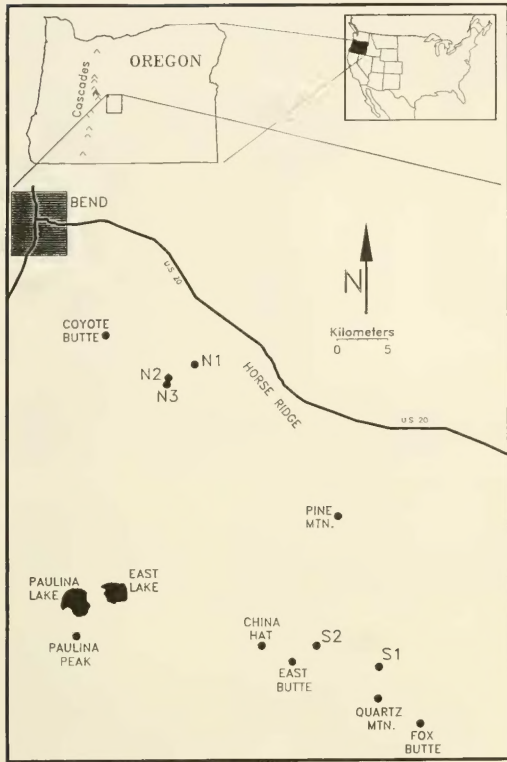


Fig. 1. Map of the study area in central Oregon showing locations of the four caves in which Townsend's big-eared bats were captured and fitted with radiotransmitters (S1, S2, N1, and N2), and location of the only known maternity cave (N3) in the basin. Telemetered bats were monitored from atop Pine and Quartz mountains, Coyote, East, Fox, and China Hat buttes.

determining bat locations. The monitoring protocol for fixed-point triangulation consisted of scanning all active frequencies for the initial five minutes of each quarter hour. If contact was made, the other observers were notified by radio and the bat was tracked continuously. In addition, seven flights were made at night by fixed-wing aircraft carrying a receiver and wing-mounted antennae and equipped with a LORAN system. LORAN fixes were integrated with simultaneous directional information obtained from ground-based receivers.

We conducted ground searches on foot and from moving vehicles. Efforts were concentrated in the vicinity of caves known to be used by bats, including caves in which telemetered bats originally were captured. These searches continued for 7–14 days following attachment of transmitters. Due to rugged topography and the distances between northern

and southern ends of the basin, only southern caves were checked systematically following tagging of the first three bats, all of which were from the southern basin. Likewise, only northern caves were checked systematically following tagging of the last three bats, all of which came from the northern basin. All caves were checked as opportunity permitted, resulting in essentially complete coverage of all known cave sites in the basin at least weekly.

RESULTS

Movements and Roost Site Fidelity

All marked females left their caves within two nights of capture and neither returned to these caves nor entered the known maternity cave (N3) during the remainder of transmitter battery life. Upon emergence from their hibernacula, all three females from the southern end of the basin moved 11–12.5 km northeast to the western slopes of Pine Mountain and did not return to the vicinity of their hibernacula in the southern end of the basin. Only female #579 was located subsequently, again on the western slope of Pine Mountain. Faint signals were received briefly from one of these females on 3 May on a precise bearing toward the then-unknown maternity cave southeast of the study area.

The most extensive telemetry data were collected for female #707, which left N1 on the second night following capture. She was located again five nights later and was tracked for the following five nights (including a series of LORAN fixes made from the air), and then to a day roost located just east of the crest of Pine Mountain, ca 20 km from N1 but only 2–4 km from where she had been foraging on the preceding five nights. Although we do not know whether she had used this roost previously, she was not found there subsequently. This bat went undetected over the next three nights and was then located for the last time on the following night. All foraging locations beyond the immediate vicinity of N1 were on the western slope of Pine Mountain, 17–24 km from N1.

Foraging locations for the fifth female (#728) were within 2–5 km of N2: southwest of N2 on one night and northeast of N2 two nights later. This bat dropped her transmitter, which we recovered 15 days after attachment, at a location 5 km west of N2 and within 1 km

TABLE 1. Summary of radiotelemetry contacts with Townsend's big-eared bats carrying transmitter units on the Deschutes National Forest in central Oregon, 1992.

Bat #	Location ^a	Max. distance ^b	Sex	Mass (g)	Dates of contact
		(km)			
558	S1	11	F	11.0	17–19 April
568	S2	11	F	11.2	17–19 April
579	S1	12	F	12.0	19 April–2 May
707	N1	24	F	10.3	28 April–10 May
728	N2	5	F	10.6	12–25 May ^c
768	N2	8	M	9.0	20–26 May

^aIndicates location of cave where bat was captured and fitted with radiotransmitter. To maintain site security, caves are designated by alphanumeric codes; S and N indicate cave location in southern and northern portions of the study area, respectively. S1, S2, and N1 were winter hibernacula; N2 was an interim roost site.
^bMaximum distance moved from cave of initial capture, as determined by radio contact with foraging bat.
^cTransmitter dropped from bat on 26 or 27 May and recovered on 27 May.

of unnamed caves known to have harbored big-eared bats occasionally in the past (L. Becker, unpublished USFS survey data).

The single telemetered male (#768) foraged extensively in the immediate vicinity of N2 upon evening emergence, then moved 6–8 km east to forage over Horse Ridge. This bat was not located again until five nights later, when he returned to N2, and was recorded over the next two nights foraging in and around the sinkhole immediately in front of N2. Although male #768 returned to roost for two consecutive days in the cave where originally captured, he then left and did not return again prior to the end of fieldwork 12 days later.

The habitat used for foraging consisted of sagebrush shrubsteppe (western slopes of Pine Mountain and Horse Ridge) and very open ponderosa pine woodland with extensive bitterbrush and interspersed areas (<5 ha) of sagebrush. Relatively little time appeared to be spent foraging in more densely forested areas.

Times of Activity

Big-eared bats emerged from their cave roosts to forage shortly after sunset, with time of emergence becoming later as day length increased in the spring (Fig. 2). Although our data are very limited, an interpretable pattern of activity can be seen in the May data. Big-eared bats foraged in the immediate vicinity of their cave roosts during the first few hours of darkness, moved to areas farther from their roost to forage (perhaps intermittently) from around midnight to within an hour or two of

sunrise, and then once again returned to forage in the vicinity of their day roost.

DISCUSSION

Continuous monitoring of movements and activity in small, cave-dwelling bats like Townsend's big-eared bat is constrained by (1) the need to minimize load mass carried by an animal, which strongly limits both strength of transmitter signal output and battery longevity, and (2) the difficulty of signal detection in landscapes of rugged, rocky topography and from within caves. Despite these limitations, a number of salient points can be deduced from our study.

Our data clearly indicated that female big-eared bats in central Oregon did not move directly from their winter hibernacula to maternity caves, but instead utilized a series of interim roost sites over a period of perhaps as much as two months. The four females marked in April were captured in winter hibernacula in the company of other roosting conspecifics. In contrast, the two bats captured in May were the only big-eared bats roosting in the cave on the dates of capture; we assumed that neither of these bats hibernated in N2 during the preceding winter, although we cannot exclude this possibility. None of the four caves in which bats were captured was used as a maternity cave.

We suggest that little fidelity to interim roost sites occurs because neither of the two females found in day roosts returned to these roosts on subsequent days. In addition, male #768 left his roost cave, returned five days later, remained for two days, and then left again for at

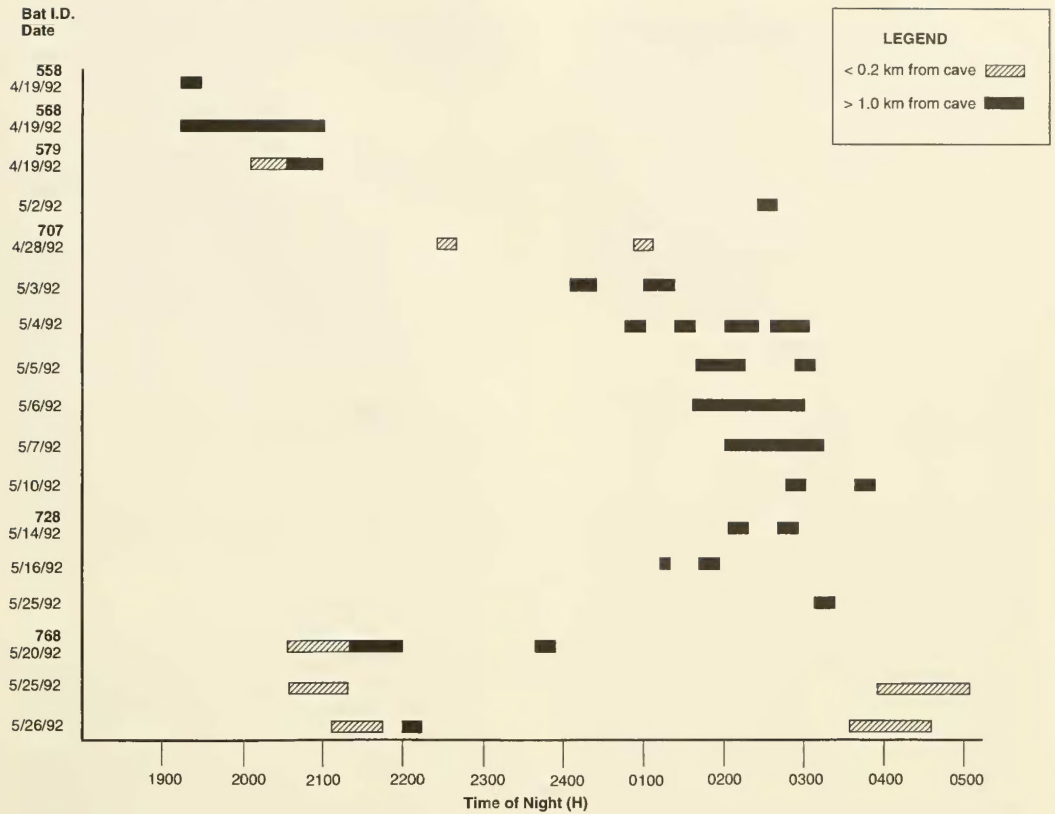


Fig. 2. Temporal distribution (Pacific Daylight Savings Time) of foraging activity by Townsend's big-eared bats in relation to distance from daytime roost sites in forested lava flows of central Oregon.

least the next 12 days. With such small sample sizes, we cannot say whether males and females differ in their use of roosts during this period or whether both sexes exhibit the same pattern of periodic use. We believe that the most reasonable interpretation of the data is that both sexes opportunistically use interim roost sites during this period, and that the choice of roost area is most likely determined by spatial and temporal variation in prey availability. Even species that exhibit strong individual fidelity to day roosts and repeated use of the same foraging areas on successive nights (e.g., *Euderma maculatum*) shift both roost site and foraging area seasonally (Wai-Ping and Fenton 1989).

Big-eared bats in our study moved up to 24 km from hibernacula to foraging areas, although our data suggest that distances moved from interim day roosts to foraging areas are typically 2–8 km during the period prior to entry into maternity colonies. These shorter

moves between roosts and foraging areas are consistent with research on eastern subspecies of big-eared bats in which females foraged at distances of 2–7 km from their roosts (Clark et al. 1993, Adam et al. 1994). Repeated use of the same foraging area on successive nights or alternation among several sites appears to characterize both eastern subspecies of big-eared bats (Anonymous 1991, Clark et al. 1993, Adam et al. 1994), as well as big-eared bats in central Oregon (e.g., bat #707).

Although big-eared bat diets are composed primarily of forest Lepidoptera, bats in eastern Oklahoma foraged preferentially at the interface between forested and open pasture habitats (Clark et al. 1993). Nevertheless, bats extensively used open, forest, and edge habitats, and significant shifts in relative habitat use were recorded by Clark et al. (1993). Similarly, in central Oregon we found that Townsend's big-eared bats foraged primarily (but not exclusively) in the more open habitats provided by shrubsteppe and forest-shrub ecotones.

In our study, activity patterns of big-eared bats in spring most closely resembled patterns documented for females of eastern subspecies during late lactation and prior to parturition (Clark et al. 1993, Lacki et al. 1994), i.e., portions of the annual cycle when females are less constrained in the amount of time they can spend away from the maternity cave. Flight initiation inside caves and subsequent emergence documented by Clark et al. (1993) and by Lacki et al. (1994) were identical to the patterns exhibited in our study.

Primary determinants of habitat suitability for Ozark big-eared bats are the availability of an adequate food supply and appropriate roost sites (Clark et al. 1995). Unlike areas where big-eared bats are limited by a small number of suitable roost sites, the extensive forested lava flows found in the Pacific Northwest offer numerous potential temporary roost sites that enable individual bats to forage over a considerable area by using a succession of roost sites during the period following emergence from their hibernaculum. Bats still are limited seasonally, however, to a very small number of sites that provide suitable microclimatic conditions for hibernacula and maternity caves. Such an interpretation of potential movement patterns is consistent with our tracking data and the loss of contact with telemetered bats for successive days followed by subsequent contact. Even our seven attempts to locate bats by aircraft, which should have avoided problems arising from topographic interference with transmitter signals, succeeded only once, indicating that bats may well have left the basin entirely, as was apparently the case for at least the one bat we detected southeast of the study area in the vicinity of the previously unknown maternity cave.

Populations of Townsend's big-eared bats inhabiting regions with extensive lava flows likely use many roost sites dispersed over large areas. The extent of movements that we documented and the use of the same foraging areas by bats from both ends of the basin make it unlikely that bats from southern and northern hibernacula represent separate populations. A better understanding of movements among seasonal and interim roost sites is urgently needed for successful conservation of dwindling populations. Our data demonstrate that the actual area of concern for management of individual populations is considerably greater

than indicated solely by locations of hibernacula and maternity caves.

ACKNOWLEDGMENTS

We thank Bijaya Kattel and Jamie Haskins for their invaluable field assistance; this study could not have been completed without their considerable help. Lew Becker of the Deschutes National Forest and Chris Carey of the Oregon Department of Fish and Wildlife contributed in many ways to the success of this project. Helpful discussions with Brad Sample and Bruce Wunder and review of earlier versions of the manuscript by Brenda Clark and William Clark improved the final manuscript. This project was carried out in part with funding provided by the United States Forest Service under Contract No. 43-04GG-2-69020.

LITERATURE CITED

- ADAM, M. D., M. J. LACKI, AND T. G. BARNES. 1994. Foraging areas and habitat use of the Virginia big-eared bat in Kentucky. *Journal of Wildlife Management* 58: 462-469.
- ALDRIDGE, H. D. J. N., AND R. M. BRIGHAM. 1988. Load carrying and maneuverability in an insectivorous bat: a test of the 5% "rule" of radio-telemetry. *Journal of Mammalogy* 69: 379-382.
- ANONYMOUS. 1991. *Endangered Species Technical Bulletin* 16: 14.
- BARBOUR, R. W., AND W. H. DAVIS. 1969. *Bats of America*. University Press, Lexington, KY.
- CLARK, B. K., B. S. CLARK, D. M. LESLIE, JR., AND M. S. GREGORY. 1995. Characteristics of caves used by the endangered Ozark big-eared bat. *Wildlife Society Bulletin*: in press.
- CLARK, B. S., D. M. LESLIE, JR., AND T. S. CARTER. 1993. Foraging activity of adult female Ozark big-eared bats (*Plecotus townsendii ingens*) in summer. *Journal of Mammalogy* 74: 422-427.
- DAHLQUEST, W. W. 1947. Notes on the natural history of the bat *Corynorhinus rafinesquii* in California. *Journal of Mammalogy* 28: 17-30.
- . 1948. *Mammals of Washington*. University of Kansas Publications of the Museum of Natural History 2: 1-44.
- DALTON, V. M., V. BRACK, JR., AND P. M. MCTEER. 1986. Food habits of the big-eared bat, *Plecotus townsendii virginianus*, in Virginia. *Virginia Journal of Science* 37: 248-254.
- DAVIS, R., AND E. L. COCKRUM. 1964. Experimentally determined weight lifting capacity in individuals of five species of western bats. *Journal of Mammalogy* 45: 643-644.
- DOBKIN, D. S., J. A. HOLMES, AND B. A. WILCOX. 1986. Traditional nest-site use by White-throated Swifts. *Condor* 88: 252-253.
- DOBKIN, D. S., B. KATTEL, AND R. D. GETTINGER. Comparative retention of radiotransmitters by fur-clipped

- and unclipped Townsend's big-eared bats and pallid bats. *Bat Research News*: in press.
- CENTER, D. L. 1986. Wintering bats of the Upper Snake River Plain: occurrence in lava-tube caves. *Great Basin Naturalist* 46: 241-244.
- HALL, E. R. 1981. *The mammals of North America*. Volume 1. John Wiley & Sons, New York.
- HANDLEY, C. O., JR. 1959. A revision of American bats of the genera *Euderma* and *Plecotus*. *Proceedings of the United States National Museum* 110: 95-246.
- HOFFMEISTER, D. F. 1970. The seasonal distribution of bats in Arizona: a case for improving mammal range maps. *Southwestern Naturalist* 15: 11-22.
- HUMPHREY, S. R., AND T. H. KUNZ. 1976. Ecology of a Pleistocene relict, the western big-eared bat (*Plecotus townsendii*), in the southern Great Plains. *Journal of Mammalogy* 57: 470-494.
- JONES, C. 1965. Ecological distribution and activity periods of bats of the Mogollon Mountains area of New Mexico and adjacent Arizona. *Tulane Studies in Zoology* 12: 93-100.
- KUNZ, T. H., AND R. A. MARTIN. 1982. *Plecotus townsendii*. *Mammalian Species* 175: 1-6.
- LACKI, M. J., M. D. ADAM, AND L. G. SHOEMAKER. 1993. Characteristics of feeding roosts of Virginia big-eared bats in Daniel Boone National Forest. *Journal of Wildlife Management* 57: 539-543.
- _____. 1994. Observations on seasonal cycle, population patterns and roost selection in summer colonies of *Plecotus townsendii virginianus* in Kentucky. *American Midland Naturalist* 131: 34-42.
- MARCOT, B. G. 1984. Winter use of some northwestern California caves by western big-eared bats and long-eared *Myotis*. *Murrelet* 65: 46.
- MARTIN, R. A., AND B. G. HAWKS. 1972. Hibernating bats of the Black Hills of South Dakota. I. Distribution and habitat selection. *Proceedings of the New Jersey Academy of Science* 17: 24-30.
- PEARSON, O. P., M. R. KOFORD, AND A. K. PEARSON. 1952. Reproduction of the lump-nosed bat (*Corynorhinus rafinesquii*) in California. *Journal of Mammalogy* 33: 273-320.
- PERKINS, J. M., AND C. LEVESQUE. 1987. Distribution, status, and habitat affinities of Townsend's big-eared bat (*Plecotus townsendii*) in Oregon. Oregon Department of Fish & Wildlife Technical Report 86-5-01.
- PIERSON, E. D. 1989. Help for Townsend's big-eared bats in California. *Bats* 7: 5-8.
- PIERSON, E. D., W. E. RAINEY, AND D. M. KOONTZ. 1991. Bats and mines: experimental mitigation for Townsend's big-eared bat at the McLaughlin Mine in California. Pages 31-42 in *Proceedings V: Issues and technology in the management of impacted wildlife*. Thorne Ecological Institute, Boulder, CO.
- ROSS, A. 1967. Ecological aspects of the food habits of insectivorous bats. *Proceedings of the Western Foundation of Vertebrate Zoology* 1: 205-264.
- SAMPLE, B. E., AND R. C. WHITMORE. 1993. Food habits of the endangered Virginia big-eared bat in West Virginia. *Journal of Mammalogy* 74: 428-435.
- SWENSON, J. E., AND G. F. SHANKS, JR. 1979. Noteworthy records of bats from northeastern Montana. *Journal of Mammalogy* 60: 650-652.
- TWENTE, J. W., JR. 1955. Some aspects of habitat selection and other behavior of cavern-dwelling bats. *Ecology* 36: 706-732.
- WAI-PING, V., AND M. B. FENTON. 1989. Ecology of spotted bat (*Euderma maculatum*) roosting and foraging behavior. *Journal of Mammalogy* 70: 617-622.
- WHITAKER, J. O., JR., C. MASER, AND S. P. CROSS. 1981. Food habits of eastern Oregon bats, based on stomach and scat analyses. *Northwest Science* 55: 281-292.
- WHITAKER, J. O., JR., C. MASER, AND L. E. KELLER. 1977. Food habits of bats of western Oregon. *Northwest Science* 51: 46-55.
- WILKINSON, G. S., AND J. W. BRADBURY. 1988. Radiotelemetry: techniques and analysis. Pages 105-124 in T. H. Kunz, editor, *Ecological and behavioral methods for the study of bats*. Smithsonian Institution Press, Washington, DC.

Received 5 January 1995
Accepted 28 April 1995